DOCKET NO.
SJO9-2001-0087US1/IBM1P006

U.S. PATENT APPLICATION

FOR

SHIELDED EXTRAORDINARY MAGNETORESISTANCE HEAD

ASSIGNEE: INTERNATIONAL BUSINESS MACHINES

KEVIN J. ZILKA
PATENT AGENT
P.O. BOX 721120
SAN JOSE, CA 95172

SHIELDED EXTRAORDINARY MAGNETORESISTANCE HEAD

FIELD OF THE INVENTION

The present invention relates to magnetoresistance heads, and more particularly, this invention relates to an extraordinary magnetoresistance head with improved operating characteristics.

BACKGROUND OF THE INVENTION

Computer systems generally utilize auxiliary memory storage devices having media on which data can be written and from which data can be read for later use. A direct access storage device (disk drive) incorporating rotating magnetic disks is commonly used for storing data in magnetic form on the disk surfaces. Data is recorded on concentric, radially spaced tracks on the disk surfaces. Magnetic heads including magnetoresistance (MR) sensors are then used to read data from the tracks on the disk surfaces.

Prior Art FIG. **1** illustrates a magnetic head **100** adapted to accommodate traditional MR sensors. As shown, a pair of shields **102** is provided with an MR sensor **104** positioned therebetween. Further, such shields **102** have a rectangular configuration defined by parallel side edges. In use, the magnetic head **100** is adapted to be positioned over a magnetic recording disk **106** with an air bearing surface therebetween.

Prior Art FIG. **2** is a cross-sectional view taken along line 2-2 of FIG. **1** again showing the shields **102** with the MR sensor **104** therebetween. As shown in FIG. **2**, the

MR sensor **104** is maintained between the shields **102** at a lower extent thereof at a point immediately adjacent to the magnetic recording disk **106.**

As is well known, the magnetic recording disk **106** is populated with magnetic flux that is representative of stored data. In use, a current is conventionally applied to the MR sensor **104,** and a voltage is monitored across the MR sensor **104**. Such voltage fluctuates as a function of a resistance of the MR sensor **104** which, in turn, fluctuates as a function of the particular magnetic fields that are present on the magnetic recording disk **106** as result of the flux. By this design, the MR sensor **104** may be used to read the contents of the magnetic recording disk **106** as the magnetic head **100** is moved.

Prior Art FIGs. **2-1** and **2-2** are cross-sectional views taken along lines 2-1 and 2-2 of FIG. **2** showing the current flow in the MR sensor **104** and the magnetic flux of the magnetic recording disk **106,** respectively. As shown, the aforementioned current flow resides in a particular plane **200**. Further, the magnetic flux **202** that is present on the magnetic recording disk **106** is parallel with such plane **200** of current flow. It should be noted that such parallel relationship between the magnetic flux **202** and the current flow plane **200** is required for traditional MR sensors to operate properly.

Recently, various institutions have recognized a new type of semiconductor material that exhibits extraordinary magnetoresistance (EMR). This is accomplished by embedding a Au metal within semiconductor material (e.g. InSb). More information on such EMR materials may be found with reference to the following article: Solin et al., "Enhanced Room-Temperature Magnetoresistance in Inhomogeneous Narrow-Gap Semiconductors," SCIENCE Journal, 1 Sept. 2000, Vol. 289, Page 1530. Further

reference may be made to US. Pat. No.: 5,965,283 which is incorporated herein by reference.

While such EMR material has been recognized as a candidate for use in storage technology, there have currently been no advancements in actual implementations of such application. One suggested reason for such lack in the art is the different characteristics exhibited by EMR material with respect to traditional materials used with MR sensors **104.** In particular, the MR sensors **104** can not simply be substituted with an EMR sensor.

As mentioned before, a field from recorded bits on a magnetic media flows in the plane of a sensor material in the case of giant MR or magnetic tunnel junction sensors. In sharp contrast, the field from the recorded bits needs to be perpendicular to the plane of the sensor material to obtain the extra-ordinary magnetoresistive effect when using EMR sensors.

One prior art solution is disclosed by Solin et al. in the "Digests of the Magnetic Recording Conference," 2001, paper C-5. Such solution provides a horizontal EMR sensor. However, this configuration is not suitable for current manufacturing methods, and is very difficult to construct.

There is thus a need for a practical application of EMR material in the storage technology domain.

DISCLOSURE OF THE INVENTION

An extraordinary magnetoresistance (EMR) magnetic head is provided including a first shield and a second shield defining a gap adapted for being positioned over a magnetic recording disk. An EMR sensor is positioned between the first shield and the second shield. In order to ensure proper operation of the EMR sensor, a plane in which the EMR sensor is positioned is perpendicular to magnetic flux associated with the magnetic recording disk.

In one embodiment, the EMR sensor may include a semiconductor material with impurities imbedded therein. For example, the impurities may include Au.

In another embodiment, the EMR head may further be equipped with a first insulator layer positioned between the first shield and the EMR sensor. Further, a second insulator layer may be positioned between the second shield and the EMR sensor.

In still another embodiment, a width of the shields at a first point on the shields proximate to the magnetic recording disk may be less than a second point on the shields distant the magnetic recording disk, where the EMR sensor is positioned. Such first point on the shield may define a trackwidth of the EMR head. At least a portion of the side edges of the shields may taper outwardly from the first point to the second point on the shields. Further, the first and second shields may be constructed from a ferromagnetic material.

In use, a current may be applied to a pair of current contacts positioned on the EMR sensor. It should be noted that the aforementioned plane is defined by a flow of

the current. Moreover, the plane may also be defined by a sensing field associated with the EMR sensor. During operation, the magnetic fields associated with the magnetic recording disk reside in the shields to afford a voltage in the EMR sensor upon an application of the current via the current contacts. A pair of voltage contacts may thus be positioned on the EMR sensor for monitoring the voltage for the purpose of reading data from the magnetic recording disk.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and advantages of the present invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings.

Prior Art FIG. **1** illustrates a magnetic head adapted to accommodate traditional MR sensors.

Prior Art FIG. **2** is a cross-sectional view taken along line 2-2 of FIG. **1** showing shields with the MR sensor therebetween.

Prior Art FIGs. **2-1** and **2-2** are cross-sectional views taken along lines 2-1 and 2-2 of FIG. **2** showing the current flow in the MR sensor and the magnetic flux of the magnetic recording disk, respectively.

FIG. **3** is a perspective drawing of a magnetic recording disk drive system in accordance with one embodiment of the present invention.

FIG. **4** illustrates an EMR read head constructed in accordance with one embodiment of the present invention.

FIG. **5** is a cross-sectional view taken along line 5-5 shown in FIG. **4** illustrating the magnetic flux associated with the magnetic recording disk.

BEST MODE FOR CARRYING OUT THE INVENTION

The following description is the best embodiment presently contemplated for carrying out the present invention. This description is made for the purpose of illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein.

Referring now to FIG. **3**, there is shown a disk drive **300** embodying the present invention. As shown in FIG. **3**, at least one rotatable magnetic disk **312** is supported on a spindle **314** and rotated by a disk drive motor **318**. The magnetic recording media on each disk is in the form of an annular pattern of concentric data tracks (not shown) on disk **312**.

At least one slider **313** is positioned on the disk **312**, each slider **313** supporting one or more magnetic read/write heads **321**. More information regarding such heads **321** will be set forth hereinafter during reference to FIG. **4**. As the disks rotate, slider **313** is moved radially in and out over disk surface **322** so that heads **321** may access different portions of the disk where desired data are recorded. Each slider **313** is attached to an actuator arm **319** by way of a suspension **315**. The suspension **315** provides a slight spring force which biases slider **313** against the disk surface **322**. Each actuator arm **319** is attached to an actuator **327**. The actuator **327** as shown in FIG. **3** may be a voice coil motor (VCM). The VCM comprises a coil movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller **329**.

During operation of the disk storage system, the rotation of disk **312** generates an air bearing between slider **313** and disk surface **322** which exerts an upward force or lift on the slider. The air bearing thus counter-balances the slight spring force of suspension **315** and supports slider **313** off and slightly above the disk surface by a small, substantially constant spacing during normal operation.

The various components of the disk storage system are controlled in operation by control signals generated by control unit **329**, such as access control signals and internal clock signals. Typically, control unit **329** comprises logic control circuits, storage and a microprocessor. The control unit **329** generates control signals to control various system operations such as drive motor control signals on line **323** and head position and seek control signals on line **328**. The control signals on line **328** provide the desired current profiles to optimally move and position slider **313** to the desired data track on disk **312**. Read and write signals are communicated to and from read/write heads **321** by way of recording channel **325**.

The above description of a magnetic disk storage system, and the accompanying illustration of FIG. **3** are for representation purposes only. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders.

FIG. **4** illustrates an EMR read head **400** constructed in accordance with one embodiment of the present invention. In one embodiment, the EMR read head **400** may be used in the context of the magnetic disk storage system of FIG. **3.** Of course, the EMR read head **400** may also be utilized in any other desired storage technology context. As shown in FIG. **4**, a pair of shields **402** is provided for being positioned over a

magnetic recording disk **404**. Such shields **402** may be constructed from a ferromagnetic material.

An EMR sensor **406** is positioned between the shields **402** at an upper extent thereof. In particular, the EMR sensor **406** is positioned between the top edges of the shields **402.**

The EMR sensor **406** may include a semiconductor material with impurities imbedded therein. In the context of the present description, the impurities may include Au or any other material that requires magnetic flux associated with the magnetic recording disk to propagate perpendicularly with respect to a plane of the EMR sensor **406**. More information on EMR materials may be found with reference to US. Pat. No.: 5,965,283 which is incorporated herein by reference. As will soon become apparent, a plane in which the EMR sensor **406** is positioned is perpendicular to magnetic flux associated with the magnetic recording disk **404** in order to ensure proper operation of the EMR sensor **406**.

In one embodiment, the EMR sensor of the present invention may include a composite of non-magnetic InSb, a high mobility, narrow-gap semiconductor and metal, that exhibits room temperature MR orders of magnitude larger than that obtained to date with other materials. Although InSb exhibits moderate MR in the unpatterned state, embedded metallic inhomogeneities (i.e. Au) may be used to engender room temperature MR's as high as 100%, 9,000% and 750,000% at fields of 0.05, 0.25 and 4.OT, respectively. This extraordinary MR occurs because at H = 0 the conducting inhomogeneity is a short circuit, as expected, but at a high field it acts, counter-intuitively, as an open circuit.

As an option, a width of the shields **402** at a first point **410** on the shields **402** proximate to the magnetic recording disk **404** may be less than a second point **412** on the shields **402** distant the magnetic recording disk **404**. Moreover, such first point **410** on the shields **402** may define a trackwidth **TW** of the EMR head **400**. As shown, at least a portion of the side edges **414** of the shields **402** may taper outwardly from the first point **410** to the second point **412** on the shields **402**.

It should be noted that the specific configuration of the shields **402** may vary per the desires of the user. In particular, the configuration of the shields **402** may be varied in order to increase the read resolution of the EMR head **400**. Moreover, any type of supporting structure may be utilized that ensures the plane in which the EMR sensor **406** resides is perpendicular to the magnetic flux associated with the magnetic recording disk **404**.

Further provided on the EMR head **400** is a pair of current contacts **420** and a pair of voltage contacts **422**. Optionally, the number and positioning of the current contacts **420** and the voltage contacts **422** may vary per the desires of the user.

In operation, a current may be applied to the current contacts **420** positioned on the EMR sensor **406**. It should be noted that the aforementioned plane is defined by the flow of the current. Moreover, the plane is also defined by the sensing field associated with the EMR sensor **406**. Note FIG. 4. Magnetic fields associated with the magnetic recording disk **404** propagate in the shields **402** as a result of the flux to afford a voltage in the EMR sensor **406** upon an application of the current via the current contacts **420**. The voltage contacts **422** may thus be used for monitoring such voltage, and thus detecting the contents of the magnetic recording disk **404**.

FIG. **5** is a cross-sectional view taken along line 5-5 shown in FIG. **4** illustrating the magnetic flux **504** associated with the magnetic recording disk **404. ** As shown, the shields **402** include a first and second shield which define a space therebetween. As shown in FIG. **5**, the space between the shields **402** at the first point **410** defines a read gap **RG** of the EMR head **400**.

Further provided is a pair of insulator layers **502**. In particular, the EMR head **400** may be equipped with a first insulator layer positioned between the first shield and the EMR sensor **406**. Further, a second insulator layer may be positioned between the second shield and the EMR sensor **406**.

As mentioned earlier, a current is applied to the EMR sensor **406** via the current contacts **420.** Further, a voltage is monitored at the voltage contacts **422** of the EMR sensor **406**. Such voltage fluctuates as a function of a resistance of the EMR sensor **406** which, in turn, fluctuates as a function of the magnetic flux **504** that is present on the magnetic recording disk **404**. By this design, the EMR sensor **406** may be used to read the contents of the magnetic recording disk **404** as the EMR head **400** is moved.

Unlike prior art devices like that shown in FIGs. **1** and **2**, the present EMR sensor **406** is positioned at an upper extent of the shields **402**. By this design, magnetic fields **505** propagate within the shields **402** as a result of the flux **504**. More importantly, a plane **540** in which the EMR sensor **406** resides (as defined by the current flow/sensing field) is perpendicular to the magnetic flux **504** associated with the magnetic recording disk **404** in order to ensure proper operation of the EMR sensor **406**.

As mentioned earlier, the EMR sensor **406** differs with respect to prior art MR sensors in this respect. By the unique positioning and resultant relative flux orientations

of the present embodiment, the application of the EMR sensor **406** in a storage environment is effectively enabled.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.